Planning for Growth: An Assessment of City and Regional Land Use Change Models for Eastern North Carolina

by

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Acronyms of Organizations and Models

CA- Cellular Automata

CUF-2- Second Generation California Urban Futures

LEAM- Land Use Evolution and Impact Assessment Model

LUCAS- Land Use Change Analysis System

SACOG- Sacramento Area Council of Governments

SACMET-Sacramento Metropolitan Travel Demand Model

SERPPAS- Southeast Regional Partnership for Planning and Sustainability

SLEUTH- Slope, Land Use, Exclusion, Urban Extent, Transportation, Hill Shade

SLI- Strategic Lands Inventory

CHAPTER ONE: INTRODUCTION

In Eastern North Carolina, increasing development rates have created several challenges for cities, towns and counties including increased housing prices, loss of wildlife habitat, water pollution, increased demand for infrastructure, and a change in community character (SERPPAS 2009). Rapid urbanization also causes problems for military installations that are threatening military training activities of the Army. Also it alters future development patterns around military installations, and presents challenges to the sustainability of defense and natural and economic resources (Westervelt 2006). Additionally, fast changing land use patterns are creating challenges for urban and regional planning authorities in both forecasting and managing new development, transportation, utility infrastructure issues, and economic forecasting and assessment (Westervelt 2006). It is important for the sustainability of this region to work collaboratively with planners, policy makers, stakeholders and citiziens to protect natural resources, balance the health and safety of communities, and promote economic development and military readiness (Deal and Schunk 2004; SERPPAS 2009). A land use change model is a tool that can effectively address these concerns.

Several meta-studies have been published that evaluate land-use change models (Agarwal 2002, EPA 2000; Berling-Wolff & Wu 2004). However, gaps are evident in the literature with regards to studies that specifically focus on city and regional level modeling needs for Eastern North Carolina. This report attempts to close the gaps and provides a study that takes a critical look at the most widely used land-use change models, assesses their capabilities, and makes recommendations regarding models that would be best used to address Eastern North Carolina concerns related to sensitive lands surrounding military bases for Craven, New Bern and Onslow Counties.

The paper proceeds as follows: Chapter Two provides background information on Eastern North Carolina and the land-use change models and types. Chapter Three discusses the methods used to choose the models, methodology used in the interview approach, and the established evaluation criteria for assessing the land use change models. Chapter Four comprise the Results, which compares and contrasts the models based on the established criteria as set forth in the methods section, and discusses results of interviews with planners and policy-makers in New Bern, Onslow, and Craven counties. Chapter Five provides a discussion based on the results section and the final chapter concludes by providing strategic recommendations for future action.

CHAPTER TWO: BACKGROUND

Eastern North Carolina lags the rest of the state for economic development; however, in recent years, parts of the region have experienced increased development in the form of retirement communities and vacation homes along the coast, estuaries and rivers and around military operating areas (Onslow County Joint Land Use Study 2003). The Southeast portion of the state especially is experiencing pressure from rapid urban growth and military expansion, and this growth and rapid suburban expansion is beginning to threaten military training flexibility, economic viability of rural communities, and sensitive ecosystems within Eastern North Carolina (Onslow County Joint Land Use Study 2003).

A number of projects have been conducted to address Eastern North Carolina issues, one of the ongoing efforts being the Strategic Lands Inventory Project (Strategic Lands Inventory Report 2008). The Conservation Fund in partnership with the NC Center for Geographic Information and Analysis is in charge of this project and works to develop compatible resource-use suitability maps for six land use types including residential, commercial, industrial, sustainable farmland, sustainable forestland, and natural resources (Strategic Lands Inventory Report 2008). These maps serve as decision support tools that provide land ownership parcels and related map-based information to support the prioritization of conservation opportunities, and support the objectives of the military bases in the region (Strategic Lands Inventory Report 2008). They illustrate the competing values between land uses as the region grows and as more resources become scarce (Strategic Lands Inventory Report 2008). Also, the Strategic Lands Inventory DVD includes a set of supporting data layers for use as inputs into a subset of land use-change models.

Land-Use Change Model Development

As mentioned, land-use change models have become a major tool used to address community concerns. These models originated in the 1950's and 1960's and were seen as the "new tool for planning" that would revolutionize urban policy (Deal and Schunk 2004; Wegener 1994; Berling-Wolff & Wu 2004). Models at this time focused on simulating land use patterns and transport at a single point in time (Batty 2003; Berling-Wolf 2004; Wegener 1994). Lee's "Requiem for Large-Scale Models", which was published in the 1970's, had a profound impact on the world of modeling by bringing into question the applicability and future of large-scale urban models in planning (Lee 1973). Lee discussed the new models and their application, and pointed out their failure at addressing new development patterns. He discussed the "seven sins of large-scale models" as being that they are: too big to be useful for decision makers, too data intensive, contain little theoretical structure, are complicated, mechanical, and too expensive (Berling-Wolf 2004; Lee 1973; Wegener 1994). Although twenty years have past since the "Requiem" was written, the urban modeling field is again coming to life with a network of urban models of varying levels of comprehensiveness (Wegener 1994). The models now address the pitfalls that Lee (1973) identified in his 'requiem" including a need for: (1) transparency, (2) robustness, (3) reasonable data needs, (4) appropriate spatio-temporal resolution, and (5) inclusion of sufficient key policy variables to allow for more significant policy questions to be explored and answered (Agarwal 2002; Lee 1973; Wegener 1994).

The state of the art of operational urban activity models continues to advance both theoretically and in ease of use as a result of the "Requiem" (Lee 1973). These advances include the incorporation of random utility theory to predict location and travel choices, and the increased use of GIS-based software to analyze data (Landis and Zhang 1998; Wegener 1994; Wegener 1995). The result is more explicit models of urban activity patterns (Landis and Zhang 1998; Wegener 1994; Wegener 1995). Also, the availability of GIS has renewed interest in computer modeling and increased the development of planning support systems that combine GIS data, computer based models, and advanced visualization techniques in an easy to use and cost-effective platform (Klostermann 1999).

Types of Models

There are four types of models that will be discussed in this paper: cellular (ca) automata, GIS-based planning support systems, agent-based/discrete choice and spatial input-output.

Cellular Automata

Cellular automata (CA) models developed from a need to include a variety of factors and functions related to growth patterns. These models are considered a simple class of models for simulating and predicting spatial patterns of urban development (Batty 1998, 1999; Jantz 2003; O'Sullivan 2001). CA models require that space be represented as a grid of cells that can change state as the model iterates (Jantz 2003; O'Sullivan 2001). The changes are regulated by rules that specify a set of neighborhood conditions to be met before a change in state can occur (Jantz 2003; O'Sullivan 2001). The cellular automation is defined by a lattice (L), a state space (Q), a neighborhood template (l), and a local transition function (f); the formulation is expressed as: A=<L, Q, _, f > (Berling-Wolff 2004; Noth et. al 2003; O'Sullivan 2001). The cell may be in one of several states, and time is discrete with cells being updated at each time interval (Batty 1998, 1999; Berling-Wolff, Jianguo Wu 2004; Noth et. al 2003)

GIS-based Planning Support Systems

GIS-based planning support systems are new forms of models designed to assist in community planning and development. Functions include the measurement of existing conditions, creation of scenarios, evaluation of alternatives, and assistance in the creation of plans (Geertman 2003). These models produce scenarios for land use planning purposes and are extensions used with GIS software (Batty 1999; Geertman 2003). They are the most simplistic of the models described and it is this simplicity that makes them of value to planning departments and regional organizations that have limited time, staffing and model experience.

Agent-Based/Discrete Choice

Agent-Based/Discrete Choice models have two basic data structures, including a representation of space in which the agents interact, and an established situation in which the agent has behaviors governed by a set of rules (Noth et. al 2003; Parker et. al 2003). The agents interact with space and with other agents, and rules are dependent upon the current characteristics of the individual agents (Parker et. al. 2003)

Spatial Input-Output

Spatial input-output models have their roots in gravity theory using linear and optimization mathematics (Hunt et. al. 2005). Gravity theory deals with the movement of people at the aggregate levels and focuses on land use change (Berling Wolff 2004; Foot 1981). Additionally, gravity theory uses modified equations stating that the spatial interaction between two entities declines in proportion to the square of the distance (Berling-Wolff 2004; Foot 1981).

In general, these models deal with the interaction between land-use and transportation (Foot 1981, Berling-Wolff 2004). Space is aggregated into zones, and each zone contains households and jobs, with the interaction between zones being a function of the zone's size and connectivity (Hunt et. al. 2005). Hybrid spatial input-output models go a step further and include behavioral and economic theory as well as the simultaneous modeling of land use and transportation (Abraham 1998; delaBarra 2001; Hunt et. al. 2005).

CHAPTER THREE: METHODS

The following approach was taken to determine, which land-use change models to analyze. First a variety of databases were queried including Google Scholar, Academic Search, and Google web searches to locate relevant land use change modeling literature. The search resulted in a list of approximately 250 articles that were analyzed to determine models for further analysis. Articles that focused on model comparisons, meta-studies, an explanation of specific model capabilities, and case study examples of models at the city and regional level were the focus of the search. The list of articles was then narrowed down to 150.

From this list of 150 articles, a list of 64 land use change models was generated. The models fall into four broad categories: cellular automata (CA) models, GIS based decision-support tools, agent based/discrete choice, and spatial input-output. A majority of models were eliminated from consideration due to their limited policy analysis capabilities, lack of relevant applications in the United States, and narrow modeling focus. An example of a model that was not chosen for further research is ProLand (Bormann 2009). This model was developed in the Netherlands and is an agro-economic model that predicts feasible land use and management scenarios based on political, economic, social and ecological conditions (Bormann 2009). The reason this model was not included was because it has not been applied at the local or regional level within the United States and the main focus of the model is on agriculture and economics as opposed to urban and regional policy (Bormann 2009).

From these 64 models, 15 models were selected (Table 1). They were chosen because they can evaluate local and regional level urban policies, they have been applied at both the local and regional scale within the last 10 years, and they can model land use change patterns at varying time scales. Also, they can interact with transportation, economic and ecological models in varying capacities. They are a diverse set; the models range from simple to complex in nature, are of varying price ranges for purchase, and are representative of the four described model types.

TABLE 1: Land Use Change Models

Model Name	Model Developer	Cellular (CA) Automatal	GIS Based Decision Support System	Discrete Choice/Agent Based	Spatial Input-Output	Implementation Examples	Citation
Land Use, Evolution and Impact Assessment Model (LEAM)	University of Illinois with funding from the National Science Foundation	X				Fort Benning Region	Deal and Schunk 2004: Westervelt and MacAllister 2006; Westervelt and Rank 2006
SLEUTH (Slope, Land use, Exclusion, Urban, Transportation, Hillshading)	Keith C. Clarke, Department of Geography, Unviersity of California at Santa Barbara	X				Pike and Wayne Counties, Pennsylvania	Claggett 2004; Dietzel and Clarke 2004; Herold 2003; Silva & Clarke 2005; Jantz & Goetz &Shelley 2003
INDEX	Criterion Planners/Engineers, Inc.		X			land use/transportation scenario modeling for Mississippi Gulf Regional Planning Commission	Criterion Planners 2009
Smart Places	Electric Power Research Institute (EPRI). Contact: Paul Radcliffe		X			Stapleton Redevelopment Project Denver, Colorado	EPA 2000; Croteau 1997
What If?	Dr. Richard E. Klosterman (as Community Analysis and Planning Systems, Inc.)		X			Hamilton County, Ohio	Klosterman 1999
Community Viz	Orton Family Foundation		X			City of Haverlock, NC 3D visualization work in the downtown	Placeways 2009
NatureServe Vista	NatureServe		X			Napa Valley, California: environmental protection and sustainable agriculture	NatureServe 2009
CUF-2 (second generation California Urban Futures)	John Landis, Institute of Urban and Regional Planning University of California at Berkeley			X		San Francisco, California Bay Region	Landis 1995; Landis and Zhang 1998
UrbanSim	Paul Waddell, Daniel J. Evans School of Public Affairs, University of Washington			X		Southeast Michigan Council of Governments	North 2003; Waddell 1998; Waddell 2002; Waddell & Borning 2004
TRANUS	Modelistica				X	Land Use and Transportation model for the Baltimore Metropolitan Area	delaBarra 2000; delaBarra 2001
METROSIM	Alex Anas & Associates				X	Pittsburgh, Pennsylvania	Anas 1987
MEPLAN	Marcial Echenique & Partners Limited				X	Sacramento, California	Abraham 1998
IRPUD	Michael Wegener, Institute of Spatial Planning, University of Dortmund, Germany				X	metropolitan region of Dortmund Germany	Wegener 1998
LUCAS	Michael W. Berry, Department of Computer Sciences, University of Tennessee				X	Little Tennessee River Basin, Tennessee	Berry 1996
UPLAN	Robert Johnston, Department of Envrionmental Science and Policy, University of California at Davis				X	San Joaquin Valley, California	Johnston 2002; Johnston et al. 2003

Interviews

A primary source of information came from qualitative interviews with planners and policy makers in three Eastern North Carolina counties: Onslow, Craven, and New Bern. The interviews were conducted in order to identify critical issues and challenges caused by growth and development in Eastern North Carolina, and to determine the local and regional land use trends and the technical capacity of local governments to plan for future growth. The four counties were chosen for interviews due to their close proximity to military bases and their involvement in the Military Growth Task Force of North Carolina's Eastern Region. In all, 10 people were interviewed in meetings that lasted 45-70 minutes. These interviews took place in person by David Salvesen and Peter Zambito on March 23-25, 2009, and followed a standard interview protocol with pre-determined questions. The interview questions may be found in Appendix A.

There were two styles of interviews conducted. The interview conducted with the Onslow County Planning department was run like a focus group with five people in attendance. The interviews with the City of Jacksonville, New Bern and Craven Counties, and the Town of Swansboro were conducted one-on-one (A list of interviewees can be found in Appendix B).

It is important to note the limitations of the interview methodology. Due to time and schedule restraints, only a limited number of participants could be interviewed; however, additional interviews will be conducted through the end of April. As a result, some relevant members of the community were not included in this round of interviews including environmental organizations, public facility offices and GIS coordinators at the municipality level, but these individuals will be contacted by the end of the month.

Model Evaluation Criteria

Six criteria were used to compare and contrast the 15 land use change models. These criteria get at the core concerns of the planning departments within Onslow, Craven, and New Bern counties. The criteria used to evaluate the models include: scale of analysis, ability to address both urban and regional policy, usability of the model based on its component's and structure, ability to interface with various impact assessment models, the potential to evaluate real estate decisions, and the model cost.

The scale of analysis refers to the ability to address low and/or high resolution and whether a model is better suited for fine scaled parcel-level analysis or addressing large regional level concerns.

Not all models are able to address urban and regional policy so understanding what type of policies the models can address, and the policy limitations, if any, that each model has, is important in determining the model's effectiveness in addressing Craven, New Bern and Onslow County concerns.

The usability of the model refers to the type of sub-models that each model contains, the information that is conveyed through the model, and its flexibility in addressing growth concerns.

The ability to interface with impact assessment models such as transportation, water quality and habitat fragmentation is important because these were factors specifically highlighted in the Strategic Lands Inventory Report (Strategic Lands Inventory Report 2008).

The ability to evaluate real estate potential seeks to understand how each model evaluates and displays real estate. For example, are model's developer driven, and can they bid against each other for preferred sites?

The cost refers to the purchase price of the model, the technical skill level needed to run the model, and how widely available the software is for planning agencies and the public.

The next several sections discuss each land use change model in terms of the defined criteria.

CHAPTER FOUR: RESULTS

Scale of Analysis

Historically, the two scales of analysis that land use change models have tended to address are the city and regional level (Deal and Schunk 2004). Regional level models can address projects dealing with multiple counties and metropolitan areas or entire regions, while city-level models require higher resolution, and can address fine scaled parcel based analysis (Deal and Schunk 2004). The models evaluated in this paper have varying levels of capacity at both spatial scales.

City Level

Out of fifteen land use change models, What If? and Smart Places specifically address city level concerns. What If? is best suited to address study areas that are larger than a single parcel and that are experiencing or anticipating rapid urbanization (Croteau 1997). Smart Places, by comparison, can address parcel level analysis in addition to small rural towns and large urban areas (Croteau 1997; EPA 2000; Klostermann 1999; Landis 1994; 1995). The spatial resolution and extent of each model is scalable based on data availability, and can be customized to meet user needs.

Regional Level

Six of the fifteen models are best suited to address single or multiple county level concerns, but less suited for fine scaled-parcel level analysis. METROSIM, UrbanSim, and IRPUD are designed for use by Metropolitan Planning Organizations with the study area broken into zones. METROSIM and UrbanSim have an unlimited number of zones that can be defined within the model, while IRPUD is currently limited to 30 zones. In each model, the size of the zone is dictated by the scale and resolution of the input dataset (ANAS 1997; EPA 2000; Wegener, 1983; 1985; 1994; 1996). UrbanSim has the added feature that it can address parcels and zones at a fine spatial scale as well as grid cells of a user-specified spatial resolution; never-the-less, its main use and strength is in regional level modeling.

Another set of models, that are able to address regional level concerns are raster-based GIS models, including SLEUTH, LEAM and LUCAS. SLEUTH and LEAM operate in similar ways in that the model can address development of land at the edges and beyond cities for multiple counties and the spatial extent is user defined (Deal and Schunk 2004). In comparison, the spatial scale of LUCAS (in which a single grid cell can potentially be defined at a 90x90 meter resolution) is defined by the scale of map inputs and not by the user (Berry 1996; EPA 2000).

City and Regional level

Of the fifteen land use change models, six are able to address equally well the city and regional level scale of analysis. These are UPLAN, MEPLAN, CUF-2, TRANUS, NatureServe Vista 2.0, and INDEX.

UPLAN uses small parcel-sized grid cells to allocate growth across several land use types (Johnston 2002). The model was designed as a tool for use by a group of planning and management professionals in San Joaquin Valley, California; however, it can be recalibrated and used in other regions and states across the nation (Johnston 2002; Johnston, Shabazian, Gao 2002). Additionally, it is considered a reasonable starter model in land use change modeling for use by Metropolitan Planning Organization's, council of governments, and county and state transportation agencies (Johnston 2002; Johnston, Shabazian, Gao 2002).

MEPLAN and TRANUS were both designed to address multiple scales of analysis including detailed urban areas, cities, metropolitan regions, states or provinces, national level concerns as well as entire countries (delaBarra 2001). Similar to UrbanSim, IRPUD, and METROSIM, a defined study area for both MEPLAN and TRANUS is broken into individual zones, but the size of the zone can vary from 100 meters to the diameter of an entire country, contributing to its broad scale of analysis (Abraham 1998; delaBarra 2000; delaBarra 2001).

CUF-2 is a vector based model that uses multinomial logit and regression techniques to allocate projected growth to individual sites based on its potential profitability, as opposed to allocating growth to zones (Landis 1994; Timmermans 2003). Land use concerns are addressed for 100m x100m hectare grid cells that are individually classified into land-use categories. The model can be applied at both the city and regional level; however it is well suited for site-by site analysis associated with development alternatives that involve land developers and builders (EMPACT 2001; EPA 2000; Landis and Zhang 1998; Timmermans 2003). Similar to other models discussed, the spatial extent can be customized based on user needs

Community Viz, NatureServe Vista 2.0 and INDEX have applicability in various planning settings and can evaluate conditions in small towns, and large cities. The models can also be used by county and regional planning authorities and local and national consultancies, and use data from parcels, census tracts, and even transportation analysis zones (Placeways 2009; Criterion 2008). Community Viz has been used for metro-area planning, land-use plans, resource management, regional plan, site suitability and prioritization. Fine scaled parcel level analysis is possible by using the 3D Visualization tool within Community Viz allowing for the analysis of site plans as well as project density and build-out (Placeways 2009). INDEX is also capable of executing studies at a coarser area-based level using land units larger than the parcel level, but running this type of analysis requires consultation with Criterion staff (Criterion 2009). Finally, the main constraint for NatureServe Vista is finding data to support the desired scale of analysis, whether it be point, pixel, polygon or larger regional applications; however, both regional and city level concerns can be addressed by each of these three models (NatureServe Vista 2009).

Urban and Regional Policy

Each of the fifteen land use change models has a range of ability levels to address urban and regional policy concerns. A model such as SLEUTH, for example, does not address urban or regional level policy at all, while models such as SMART PLACES, NatureServe Vista and What If?, involve the interaction of planning and policy makers and address policy related concerns through scenario formation (Claggett et. al 2004; Dietzel and Clarke 2004; Klostermann 1999).

What If? determines what would happen if the underlying assumptions in a scenario are correct by identifying alternative policy choices. It allows users to choose between alternatives, and determine their likely effects. By comparison SMART PLACES land use scenarios' are created through interactive digitizing (Croteau 1997; Klostermann 1999). Future population and employment trends, assumed household characteristics, and anticipated development densities are policies that What If? displays; while Smart Places addresses alternative land use scenarios in terms of land use balance, water use, solid waste, water generation, and transportation and energy consumption (Croteau 1997; Klostermann 1999). NatureServe Vista 2.0 on the other hand, focuses on policies related to the environment, conservation, resource management and transportation (NatureServe Vista 2009). The program is designed to allow users to develop land use and resource management scenarios and implement these scenarios to see the resulting effect (NatureServe Vista 2009).

A number of models can address land use and transportation policy concerns including IRPUD, TRANUS, UrbanSim, LEAM and MEPLAN. IRPUD is unique because of its ability to address global policy along with local policy impacts that are associated with industrial development, public facilities and housing (Wegener 1998). TRANUS and UrbanSim both are considered land use-transportation interaction models building off of the recognition of the strong interaction between these two components and a growing focus on state growth management programs (Waddell 2003; UrbanSim 2009). Out of these five models, UrbanSim is a true policy-related model that can create alternative forecast scenarios and land-use policy assumptions, while users of TRANUS can address land use controls, urban development plans, and impacts of specific urban projects such as shopping centers or industries, regional development plans, housing plans or incentives, environmental protection plans, existing and new road improvements, public transportation reorganization, mass transport systems, restrictions to automobile use, park-and-ride, and rehabilitation of highways (delaBarra 2001; UrbanSim 2009).

LEAM involves the modeling, visualizing and testing of land-use policy impact decisions (Deal and Schunk 2004). Planner's and stakeholder's identify local factors that are causing land use change in a region and then a region-specific model is developed based on the outcomes (Deal and Schunk 2004). Additionally, planners and stakeholders can identify how future policy scenarios relate to future transportation projects, economic development, urban infrastructure improvements, resource protection, agricultural land preservation, new road construction, and changes in the regional economy (Deal and Schunk 2004).

MEPLAN takes an economic approach to modeling housing and land use location preferences and considers both the direct and indirect effects of land use and transportation systems in the determination of land use and transportation costs (FHWA 2007). The model is focused on the interaction of land use and transportation interactions and is designed to model three market equilibrium including the labor market and job assignment, the housing market and commercial space (FHWA 2007).

Unlike land use-transportation interaction models CUF-2, UPLAN and LUCAS are unable to address transportation policy. The three modules contained within the CUF-2 model focus on policy concerns related to: future population projection, households and employment, environmental concerns, land use zoning, and current density and accessibility characteristics of all sites; while LUCAS and UPLAN, more generally, address housing and land use (Berry 1996; Johnston 2002; Landis and Zhang 1998).

Community Viz and INDEX are both effective visioning tools. Community Viz allows for the calculation of the amount and location of growth overtime by performing a build-out analysis to calculate future potential, create maps, and identify 'high risk' sensitive areas in a county or region as a whole (Community Viz 2009). Additional policy impacts such as urban growth boundaries, site suitability analysis, or density restrictions can be further understood through use of Community Viz, which can then be communicated to the public through a growth visualization tool called Time Scope (Placeways 2009). INDEX presents an opportunity to visualize, evaluate, and rank alternative future scenarios based on a set of indicators. With INDEX, communities may customize stakeholder analysis, weighing local policy and planning concerns that involve land use, transportation, urban design and the environment (Criterion Planners 2008).

Usability

Land Use-Transportation Interaction

TRANUS, SLEUTH and LEAM are models that are more comprehensive because they address the relationship between land use and transportation. SLEUTH and LEAM operate in very similar ways, while TRANUS differs in its approach.

TRANUS integrates a set of three models including land use, transport, and evaluation, with feedback loops between the land use and transport modules (delaBarra 2001). Noted for its flexibility and complexity in addressing land use and transport policies, TRANUS provides a graphical user interface that is linked to databases representing different scenarios such as social, environmental, financial and economic effects (Miller, Krirger and Hunt 1998).

SLEUTH and LEAM are very similar in structure in that space is represented as a regular grid of cells that changes based on a set of simple rules as the model iterates (Claggett 2004; LEAM 2009). Each model is calibrated to simulate urban development patterns over a historic time period and then forecast these patterns into the future under a set of exclusion layers that represent land use (Claggett 2004). Within the urban growth module of SLEUTH, urban dynamics is simulated using four growth rules including: spontaneous new growth, which stimulates the random urbanization of land, new spreading centers, which simulate the development of new urban centers, edge growth, which represents the outward spread of existing urban centers, and road-influenced growth, which simulates the influence of the transportation network on development patterns (Claggett 2004). In comparison, LEAM recognizes and simulates actions based on probable economic, environmental and social impacts (Deal and Schunk 2004). The LEAM modeling approach begins with drivers, which are developed as a sub-model that is run simultaneously in each raster-based grid cell and then is linked to form the main model framework and produce landscape simulation scenarios (Deal and Schunk 2004). All driver models figure into creating the development probability model while the impact models respond to the land use change that is effected by the development probability model (Deal and Schunk 2004). LEAM currently has the following components: Land Price, Economic factors, population factors, social factors, geographic limits and factors, transportation mechanisms and factors, utility and infrastructure requirements, neighborhood development factors, resource limitations and factors, open space requirements, and stochastic scenario drivers (Deal and Schunk 2004).

Out of the 15 models, LUCAS is the only model that is programmed in C++ and operates on a UNIX workstation. It has a graphical user interface that handles interactions between the LUCAS modules and the user, communicates between system modules, and displays model outputs similar to what was just discussed for LEAM and SLEUTH (Berry 1996). There are three subject models linked by a common database in LUCAS that simulate changes in land cover over time in the areas of socioeconomics, geography, and environmental information (Berry 1996). The socioeconomic module is used to develop transition probabilities associated with changes in land cover with the driving variables including transportation networks, slope and elevation, ownership, land cover and population density. The second module is the landscape-change model, which receives input from the transition matrix that was produced in the socioeconomic models, and accesses the same spatial database of driving variables (Berry 1996). The third module focuses on environmental impacts and uses the land-cover maps that were produced by the landscape-change module in order to estimate impacts to select environmental and resource supply variables. The environmental variables include the amount and spatial arrangement of habitat for selected species, and changes in water quality caused by human land use with potential resource-supply variables including timber yields and real estate value (Berry 1996).

Policy Oriented Framework

UrbanSim integrates planning and analysis of urban development as well as incorporates the interactions between land use, transportation, and public policy (Miller and Kriger and Hunt 1998, EPA 2000, Timmermans 2003). UrbanSim schedules each model to operate once per simulated year with cells being cross-referenced to Traffic Analysis Zones for indexing travel model outputs (Waddell 2003, UrbanSim 2009). The data storage formats used in UrbanSim include: SQL database, binary files, and tab-delimited files, which allow for indicator values to be computed in minutes rather than in hours (Waddell 2008). A major strength of UrbanSim is in its ability to disaggregate households, businesses and land use with its main outputs including: future year distributions of population, households by type, businesses by type, land use type (both standard and user-specified), units of housing by type, square footage of nonresidential space by type, densities of development by type of land use, and prices of land and improvements by land use (Waddell 2003). The model components involved include the accessibility model, the economic transition model, the demographic transition model, employment location model, household location model, real estate development model and the land price model (Waddell 2003).

The California Urban Futures Model-2 has a policy-oriented framework for simulating how development and growth policies might alter the location, pattern and intensity of urban development; it includes multiple urban land uses (single family, apartments, retail, office, industrial), allows these land uses to bid against each other for preferred sites, and allows sites that have been previously developed to be redeveloped into different uses (Landis and Zhang 1998). The two primary units of analysis are political jurisdictions and developable units and the four main components of the model include: activity projection, spatial database, land use change sub-model and the simulation engine.

Unlike TRANUS, which contains feedback loops between models, the IRPUD model is driven by supply and demand in which the choice in the submarket is constrained by the supply of jobs, vacant housing, vacant land, vacant industrial and commercial space and is guided by the attractiveness of the location (Wegener 1998). Similar to LEAM and SLEUTH, the model consists of a series of simulation periods; however, in the case of IRPUD, location decisions are based on industry, residential developers and households, resulting migration and travel patterns, construction activity, land-use development, and the impacts of public policies in the fields of: industrial development, housing, public facilities and transport (Wegener 1998). The major variables in the model include: population, employment, residential buildings and non-residential buildings with the actors being: individuals or households, workers, housing investors, and firms (Wegener 1998). The actors interact within five urban development submarkets including: labor markets of new jobs and established jobs; new firms and firm relocations; housing market: both new and established; land and construction market: new, old and demolished; the transport market, which includes trips, and additional inputs including forecasts of regional employment and population (Wegener 1998).

Economic and Mathematical Framework

While some models, such as UrbanSim, are policy driven, models such as MEPLAN and METROSIM have an economic and mathematical framework to model land use-transportation interactions and policies at the metropolitan level (Abraham 1998). METROSIM can produce a one-shot long run equilibrium forecast for transportation and land use in a particular metropolitan area or can operate in annual increments and produce yearly changes to transportation and land use from existing situations until achieving a steady state. The transportation model within MEPLAN allows for a detailed examination of transportation infrastructure plans as well as results that describe the conditions of various transportation networks (Abraham 1998). The model also considers the housing market in detail through the use of classic bid-rent theory, where individuals can select their residential location as a compromise between their willingness to pay for a residence at a location, the associated transportation cost, and its influence and effect on the location of the population (Abraham 1998; EPA 2000). Once this has been resolved it is fed into a four stage transportation-land use model, which considers several effects that congestion can have on distance, trip generation, trip distribution and residential location (Abraham 1998). METROSIM contains the following seven sub-models and sectors: basic industry, non-basic industry, real estate (residential and commercial), vacant land, household, travel demand for commuting and non-work travel, and traffic assignment (ONE DOT 2003).

Arc View Extensions

A number of models run in Arc View including UPLAN, NatureServe Vista, SMART PLACES, What If?, Community Viz, and INDEX. SMART PLACES serves two functions, both of which are serviced through a single user interface and include: supporting land use scenario design and supporting land use scenario evaluation (Croteau 1997, EPA 2000). SMART PLACES data structure, user interface components and outputs allows for planners to analyze suggested changes in a land use plan and produce a text report and graphics that summarize the associated impacts (Croteau 1997).

UPLAN consists of a mask grid, which consists of exclusion areas such as lakes, open space and existing built-out, and attractions grids, with each development attraction surrounded by a user-specified buffer. The user inputs demographic and land use density factors, which are converted to hectares and then prepares a conversion for land consumed for industry and commerce and uses workers per household, percent of workers in each employment class, and average land area per worker (Johnston 2002). The calculations produced result in a table of land demanded for each land use type (Johnston 2002). A Suitability grid is produced based on the overlaying of the Attraction Grid and Mask Grid and this becomes a template for the allocation of projected land consumed in the future (Johnston 2002). The model allocates future development starting with the highest-valued cells and as higher-valued cells are consumed the model looks for lower-valued cells until all of the hectares of the projected land consumption are allocated (Johnston 2002). Within the model it is assumed that development occurs in areas that are attractive due to their proximity to existing urban areas as well as transportation facilities (Johnston 2002). Additionally, within UPLAN, urban growth falls into a series of discrete land use categories including: industrial, high-density commercial, low-density commercial, high-density residential, medium-density residential and low-density residential (Johnston 2002).

NatureServe Vista 2.0 integrates conservation information with land use patterns and policies and is a tool that helps manage natural resources and monitor land use and resource management plans (NatureServe Vista 2009). The model receives additional support from the Argos extension, Spatial Analyst (NatureServe Vista 2009).

Community Viz is designed to help people visualize, analyze and communicate about important land use decisions (Placeways 2009). It is a customizable and flexible platform made to address a wide range of purposes with some applications being very easy to understand and others requiring a deeper knowledge of GIS.

INDEX is considered a support tool intended to inform rather then as a regulatory device intended to control with the two main INDEX suite planning support tools including Plan Builder and Paint the Region. To assess scenarios, Plan Builder 9.2 offers

80 indicators, including land-use and urban design, housing and employment, pedestrian environment and transit orientation, open space preservation, storm water runoff, and water and energy efficiency. Plan Builder's companion support tool is an interactive tool designed to support regional growth visioning, multi-jurisdiction applications, and web- or personal computer-based planning, which allows for future land-use transportation scenarios to be created by drawing desired community features and "painting" population and employment growth according to desired land-use types.

What If? uses uniform analysis zones of consistent slope, zoning and municipality designation, that are GIS-generated polygons, to allocate projected land-use demands, and then derives regional conditions by aggregating the values for the land units (Klostermann 1999). Uniform Analysis zones are GIS-generated polygons which are homogeneous throughout the model so that there is a consistent slope, zoning and municipality designation (Klostermann 1999). Suitability, growth and allocation are the three main components in the What If? menu option, which relate to three procedural steps including land-use suitability, projecting land-use demands, and allocating projected demands that are incorporated into the model (Klostermann 1999). The What if? model has a land use suitability component that weights and rates procedures and can either be created or modified. Demand for land is considered by converting land use categories: residential, industrial, commercial, preservation and locally oriented uses into associated future land use demands (Klostermann 1999). Future land use demand patterns are projected by allocating land use demands that are derived from a user-selected growth scenario to different locations based on their relative suitability as defined by the assumptions of a user-selected suitability scenario (Klostermann 1999).

Interfacing with Impact Assessment Models

Transportation

Out of the 15 models, 14 can interact with transportation models. The only model that does not have this capability is CUF-2. LEAM has been successfully "coupled" with complex transportation models so that it can be used to show both direct and indirect land use effects associated with new links, roads, interchanges, and access to the transportation system (Avin 2007). UPLAN has been successfully linked to transportation models such as SACOG's Minutp-based travel demand model, and SACMET, in the Sacramento region of California while MEPLAN has a self-contained transportation model that describes conditions of transportation networks and transportation infrastructure plans (Anas 1998; Johnston 2002). METROSIM takes into account how transportation projects affect locational patterns of demand for land uses and also allows basic and service employment to respond to transportation changes through labor market and business location (Federal Highway Administration 2007). Community Viz can make traffic and transportation estimates as well as measures the impact of new roads; however, unlike LEAM, METROSIM or MEPLAN, it does not demonstrate the direct and indirect land use effects that are associated with these transportation changes. INDEX's new version, Smart Growth INDEX, has successfully interfaced with Tranplan, Minutp and Viper travel model systems software (Criterion Planners 2008). Additionally, INDEX software has successfully been used with ESRI's Network Analyst to simulate multi-modal travel conditions including walking, biking, and bus or rail transit. Network Analyst can also gauge travel mode availabilities, distances, and route directness for various design scenarios allowing for the characterization of every household's access to services and amenities (Plan Builder 2007). UPLAN is able to integrate travel modeling with GIS land use allocation; however, it lacks sophistication and ability to link with regional travel models (Johnston 2002).

The IRPUD model consists of six interconnected sub-models that can address impacts related to housing, transportation and public programs: The transport sub-model calculates work, shopping, service, and education trips for four socioeconomic groups and three transportation modes including: walking/cycling, public transport, and car. TRANUS can represent both freight and passengers, and public and private modes all within a single or common network with different vehicle types able to compete for road spaces (delaBarra 2001). For regional or national level applications, passengers and freight are both represented with similar importance (delaBarra 2001). Also, UrbanSim interacts with travel modules. The model encodes the behavior of agents in the simulation and can be shared across models allowing for fine-scale analysis for transportation networks (EPA 2000, Noth 2003, Waddell, et. al. 1998, Timmermans 2003).

Water Quality

Three of the 15 models can address water quality impacts at varying levels of capacity including: LEAM, LUCAS and INDEX. A model such as LEAM has a separate impact assessment model called LEAMwq that presents analysis of land use change impacts on water resources for specific watersheds; provides information on how future land use change can effect flooding in the region, addresses which watersheds are facing the greatest risk to water quality for a variety of pollutants, and can estimate the impacts of conservation strategies to improve water quality and reduce the risk of flooding (Choi 2005). LUCAS, in a similar way, addresses water quality caused by human land use. A model such as INDEX, which is a GIS based decision support system, is able to address impacts on water quality through a set of indicators. INDEX has 80 indicators; however, the indicators directly related to water quality include: storm water runoff, nonpoint source pollution and imperviousness (Criterion Planners 2008).

Habitat Fragmentation

Out of the 15 models Community Viz, NatureServe Vista, LUCAS, and LEAM can interface and interact with habitat fragmentation models. Community Viz uses a Landscape Fragmentation Geo-processing tool in the form of a landfrag wizard and for more advanced GIS users, an ArcToolbox “geo-processing tool” to address habitat fragmentation. The tool allows for users to measure the impact of new roads, buildings and other development on the natural landscape and on forest resources through scenario simulation (Placeways LLC 2009).

NatureServe Vista 2.0 evaluates species distribution and conservation goals against established land use scenarios such as a series of alternative land use designations and management practices (NatureServe 2009). The scenario evaluation allows for the evaluation and comparison of alternative conservation and land use scenarios and measures the progress of the strategies and scenarios against defined conservation goals (NatureServe Vista 2009).

LUCAS is able to address environmental impacts associated with the spatial arrangement and amount of habitat for species. It also can address water quality changes caused by human land use and can generate output maps that show the amount of plant and animal species within a defined habitat (Berry 1996).

The most advanced of the habitat fragmentation impact assessment models is LEAMFrag, which is a component of LEAM. The model can address the location of patches, the connectivity between patches and population size estimates (Aurambout 2005).

Real Estate Evaluation Potential

There are varying approaches to the way that real estate, development and land use decisions are addressed within each model. CUF-2, for example, is a developer driven model that includes 7 multiple land use types such as single family, apartments, retail, office and industrial, and allows them to bid against each other for preferred sites as well as allows developed sites to be redeveloped into different uses (Landis and Zhang 1998). The land use change module, considered the demand side, is at the heart of the model.

This model is in contrast to UrbanSim whose model components reflect key household, business, developer and government choices, and their interactions within the real estate market by dealing directly with the principal agents in the urban market and choices made about location and development (Waddell 2002). UrbanSim uses 24 development types, represents demand for real estate at each location, and represents the action choice processes that influence real estate processes and urban development patterns (Waddell 2002, Noth 2003). If jobs or households are predicted to move than the space occupied is flagged in the program and that space becomes vacant. When that space becomes assigned to a particular housing unit or job space than the space is reclassified and occupied. Each model encodes the behavior of agents in the simulation and objects that are operated upon, which include land parcels and buildings (Noth 2003).

TRANUS is an integrated operational set of three models including land use, transport and evaluation with dynamic simulations being created by feedback loops between the land-use and transport modules. The land use model specifically deals with the location and interaction of activities and the associated representation of the real estate market (delaBarra 2001).

In contrast, the What If? model is user defined in which the rules for constraints and attraction to development are dictated by the user (Johnston 2002). A drawback of What If? is that it does not utilize random utility or discrete choice theory to explain and project the behavior of urban actors, nor does it represent interlinked markets for land, nonresidential uses, labor, infrastructure, or housing and price adjustment regarding shifts in demand and supply (EPA 2000, Klosterman 1999).

SLEUTH is a probabilistic model that uses Monte Carlo routines to generate growth simulations. During a simulation, each calibration is compared with the control years within the time series, and average fit statistics are produced to measure the performance of a set of coefficient values in reproducing the observed urban patterns and rates of growth in the future (Claggett 2004; Dietzel and Clarke 2004; Silva and Clarke 2005). Four types of urban land use change are simulated with this model including: spontaneous growth, new spreading center growth, edge growth and road-influenced growth, which all fall into one of two categories: urbanized or non-urbanized (Claggett 2004; Dietzel and Clarke 2004; Silva and Clarke 2005).

MEPLAN has a mathematical framework with roots in the Lowry model where the housing market is considered in detail as well as its influence on the location of population within the land use and economic module. (Abraham 1998). Classic bid rent theory is at the core of this model where individuals select their residential locations as compromises between their willingness to pay for residence at a location, and the related transportation costs (Abraham1998).

Models such as INDEX, Smart Places, UPLAN and Community Viz are based on scenario based planning and are able to address real estate potential through scenario building and build out analysis (Community Viz 2009; Criterion 2009; Johnston 2002; Klosterman 1997).

Cost

Free Download

The least costly of the 15 land-use change models are those that are a free download from the developer's website including LUCAS, UrbanSim, UPLAN and SLEUTH. Free download encourages feedback, use, and a broad distribution; however, the listed models also happen to be the more technically sophisticated models to operate (Waddell 2003; Waddell 2008).

$0-$5000

Models that serve as ArcGIS extensions such as What If?, INDEX, and Community Viz come with an associated cost that varies depending on the package that is purchased. For example, What If? has different prices for professional use and for academic use. A single user's professional price for What If? is $2495, while the academic price is $250 (EPA 2000). There is not an additional operating cost for What If, since it requires ArcGIS to run, but there is a $1,000/year maintenance cost to upkeep the program (EPA 2000).

INDEX can be purchased in standard or custom versions as an Arc Map Extension (Criterion 2009). The standard price of PlanBuilder, which is one of the component's of INDEX, is $1900 while optional training sessions and technical support can be added ranging from $500-$3000 dollars (Criterion Planners 2009). The software can also be customized by the developer and the price will vary according to the customization.

The price of Community Viz varies depending on the package that is purchased. For the Professional package the price is $750.00, which includes: Scenario 360 decision-making framework and interactive analytics; Site Builder 3D visualization software for creating photo-realistic 3-D scenes; 12 months of full-service technical support; 12 months of free upgrades; and premium features (Placeways 2009). For an additional $745.00, Model Builder 3D can be purchased which allows for the creation of custom 3-D models for use in Site Builder 3D. The least expensive option is to purchase the CommunityViz -Self-Service option, which is $279.00 and does not include technical support (Community Viz 2009).

Over $10,000

METROSIM, MEPLAN, and TRANUS are the most expensive models to implement based on available cost estimates. The cost to purchase METROSIM is $20,000-$30,000, while there are additional costs to run the software ($2500 for three initial runs), train to use the software ($10,000), and maintain the software over time ($5,000-$10,000/year) (Abraham 1998; EPA 2000). The purchase price for TRANUS is $7500; however, a two week training course can range from $8000 or higher (delaBarra 2001). MEPLAN has a purchase price of $25,000 with additional costs associated with maintenance and training (Abraham 1998).

Contact the Developer

Another set of models does not have a defined cost of purchase available on their website. The developer needs to be contacted. Models that fall into this category include: NatureServe Vista, Smart Places, LEAM and IRPUD.

Interviews

The following section discusses the interviews that were conducted on March 25-March 27, 2009 by David Salvesen and Peter Zambito from the Institute for the Environment. Interviews were conducted with the Military Growth Task Force of North Carolina's Eastern Region to understand growth challenges; while the Onslow County, town of Swansboro, the City of Jacksonville, Craven County and the City of New Bern's planning department's were interviewed to understand, growth related issues and their technical capabilities.

Military Growth Task Force of North Carolina's Eastern Region

In an interview with James Bender of the Military Growth Task Force of North Carolina's Eastern Region, also mayor of Polocksville, he discussed military related growth in the region. He stated that in October 2007, the Marines announced plans to "grow the force" in NC from 186,000 to 202,000. There will be 11,477 new personnel at Camp Lejeune, Cherry Point and New River with about 8,000 of the personnel having already moved to the area and 1500 of the remaining 11,477 going to Cherry Point. To plan for this growth, Marstel Day consulting firm of Fredericksburg Virginia, and Kimley Horn, with offices in North Carolina, is developing a regional plan for the entire Eastern Region. It will be the responsibility of the military growth task force to implement the plan once it is developed.

Currently there are seven counties with 53 municipalities in the Eastern Region. Mr. Bender discussed the relationship between the task force and the surrounding municipalities. Many of the people living in the small towns, for example in Duplin and Craven Counties, do not see the relevance of the task force, because of their distance from the base. For example, he mentioned water reclamation, which is an issue for the task force to address, but not one that would really help Craven or Duplin counties, where most residents rely on septic systems and wells.

Growth related issues

Growth is expected to occur in a 35 mile buffer area around the base, although some spillover is expected in smaller towns such as Richlands, Maysville, the Carteret County corridor, and potentially in surf city and Topsail. Also there is about $3.5 billion in construction activity around Camp Lejeune and Cherry Point in New River.

Mr. Bender identified the biggest regional issue in the Eastern Region as congested roads, especially along Highway 17, which have four lanes in Craven and Onslow Counties, but only two lanes in Jones County. He identified water and sewer and beach and sound access as other issues of concern.

In order for the task force to work, he asserted that you have to make sure that everyone gets something. That is, each county must gain something from the growth. The task force has been set up to assure that counties with the biggest impact get the most votes. Thus, Onslow and Craven County each get five votes on the task force, while other counties get only two or three votes each.

Onslow County

Main Issues

The interviewees from the Onslow County Planning Department (names are in Appendix B) indicated that theirs is a fiscally conservative county having one of the lowest tax rates in the state, and that there are fiscal challenges associated with sprawl as development spreads into the countryside. Areas identified as being major locations of growth include:

- Southwest part of Jacksonville towards Richlands
- Snead's Ferry: includes some retirement and resort development with wastewater being a potential problem
- Swansboro: primarily second home development
- White Oak: has been growing but at a slow rate

The interviewees stated that some of the current concerns revolve around the supply of affordable housing, traffic congestion and the need for more schools to accommodate current over-crowded conditions. Additionally, the goals and desires of the county include seeing more infill development, increased density, increased regional coordination, and more collaboration between elected officials, planners and staff. Currently most collaboration occurs only between the politicians.

The main infrastructure needs identified by the county include: roads, schools, and water and sewer (difficulty extending water and sewer). Additional issues include loss of agricultural land, loss of commercial fishing industry, emergency services (especially fire protection), and affordable housing.

Technical Capabilities

The interviewees stated that although Onslow County has a GIS department that produces maps, it currently does not perform any land-use modeling. The GIS department does have the extension capabilities for modeling, but they need to find the time to use new and existing tools. They indicated that to use a land use model, they would need to find a simulation tool that could evaluate traffic and also a build out analysis in order to be most helpful for their efforts

Town of Swansboro

The interviewee described the Town of Swansboro as being a fast-growing community that has been affected by the economic downturn over the last year. She described how the town had five subdivisions underway last year; but that everything now has come to a halt, with only about 5-10 homes being built in the town to-date.

Technical Capabilities

Swansboro employs one person in the planning department and relies on the Onslow County (which has all of their tax information) GIS department for mapping needs. Other data is obtained from the county, but they have no independent GIS system or modeling capabilities. The interviewee indicated that if the Town of Swansboro was to use a model, then projected residential land use would be the most useful feature.

Jacksonville

Main Issues

The major growth-related challenge in Jacksonville is sewer capacity. The city has reached 80% capacity and has had to build additional capacity. This has reduced Jacksonville's growth in recent years, has limited the sewerage rationing and growth farther out, and has made it difficult to sewerage back to the plant. In the next 10 years, a need for further sewer capacity expansion is expected.

Also, both interviewees recognized a need for more communication between the city and the military base on planning issues as there have been situations where the city's planning efforts were foiled by military actions that were not coordinated. For example, the military put a large vehicle bridge next to where the city put a pedestrian bridge, which gets at the problem that there is not an official liaison between parties to coordinate efforts.

Growth Related Issues

Areas identified as the fastest growing include: Western Blvd Corridor and recent growth to the southwest of the city adjacent to Camp Lejeune. This particular area, next to Camp Lejeune, is close to the airport runway and is susceptible to noise and accidental damage from operations. Additionally, the city is planning to annex land adjacent to the base on the east flank. The military is not generally concerned about this development, but they occasionally come to rezoning public meetings in order to voice their concern about issues.

In the next 10-20 years, more development is expected on the southwest part of the city and on the north and northwest portions. To plan for this growth, water treatment capacity is being expanded. Additionally, there is a desire for more compact infill development closer to downtown and close to existing infrastructure. In these areas of expected growth there will be more neo-traditional neighborhood development that is incorporated in the current land use plan than is being developed. There is also a neo-traditional zoning ordinance in the works that will be applied to large undeveloped parcels

Technical Capabilities

The GIS department is housed in the IT department in Jacksonville, but currently it is not focused on planning needs. In terms of computer modeling capabilities, the town has the ability to model future land use, but the interviewee did not know how this is being done or who in the IT department is in charge of such requests.

Craven County

Main Issues

Transportation and water and sewer infrastructure were identified by both interviewees as the main growth related challenges in Craven County. Part of the reason that transportation is a challenge is that traffic has been noted as increasing faster than overall growth. They also agreed; however, that the main growth-related issue that the county is expected to face over the next 10-20 years is the need for expansion of water and sewer services and additional classrooms for schools.

Technical Capabilities

The interviewee indicated that Craven County does have a GIS application that will follow services such as water, sewer, and roads and that can predict high density development. Additionally, the county can do scenario analysis for different development patterns, with zoning and infrastructure as variables; however, neither the planner nor the county manager indicated, which model they are using to perform this analysis.

New Bern

Main Issues

The town is growing at a medium pace with new-comers being mostly retirees. Quality of drinking water is a major issue for New Bern. New Bern has been forced to use some water from an aquifer with lower quality water, which costs more to treat. An additional concern relates to downtown revitalization. The interviewee stated that New Bern is making sure that the downtown continues to gain investment and infill and that the town develops in a sustainable, walk-able and mixed-use manner. The downtown revitalization of New Bern is regarded as a success and the downtown is expected to be a driving force that will bring more people into the area. The interviewee indicated that this new growth pattern will be essential for the success of downtown.

Growth Related Issues

The town has changed over the last 5-10 years in that there has been an influx of affordable starter homes and also expensive houses. Areas that are experiencing the fastest growth in New Bern are along highways 17 and 43 and near the center of town. The trend in development is expected to follow that of modest housing with a lot of redevelopment of pre-WWII areas in the downtown, as well as development in the suburban areas on the new 43 connector and along highway 70 and US17. Infrastructure needs expected for future growth include roads, water and sewer, and schools.

Growth is expected to be focused around the downtown and surrounding areas as well as around places where services exist. The main environmental challenges associated with growth and development center on water quality issues from runoff associated with development. The city follows the state standards, but New Bern is not involved with the Cap Trade nutrient program. It discharges treated waste water into local lakes instead of discharging it into rivers. New Bern is not involved in protecting ground water recharge areas and feels they have the water capacity that they need.

Technical Capabilities

The interviewee identified two points that New Bern could benefit from including more regional cooperation and political will as well as some land use modeling help for areas affected by residential growth, water quality and transportation.

CHAPTER FIVE: DISCUSSION

The Eastern Region is experiencing significant growth and expects 3,500 additional military personnel to move to the area. With this growth come challenges for water and sewer capacity, supply for more homes, and to fortify transportation and infrastructure. Interviewees from New Bern, Craven and Onslow County emphasized that these were main growth concerns. They indicated that a model equipped to address transportation, water quality, water and sewer infrastructure as well as a build out analysis would be useful. As the counties have limited funds, limited staff, and limited time to devote to models, incorporating a sophisticated high cost model that requires calibration and special training would go to waste. Instead, an easy to use platform that can be integrated with GIS and that can address parcel-based and city level concerns would be the most useful to each Planning department.

Each of the 15 land use change models has associated strengths and weaknesses depending on how and where they are used. CUF-2, which is designed for use in California, and IRPUD, which has its most recent applications in Europe, requires re-calibration for use in North Carolina. TRANUS, METROSIM, MEPLAN and LEAM, are costly, require training, additional staffing and a significant time commitment to gain useful results.

METROSIM and MEPLAN that have a mathematical and economic structure, and LUCAS, which is routed in the C++ programming language, require specialized training for use. TRANUS, although specially designed to address land use and transportation interactions would require time to understand the model and run it at its fullest capabilities. Also, it is one of the most data intensive models of the fifteen.

Although CUF-2 has a well developed residential component that allows agents to bid against each other for specific sites, it is unable to address transportation concerns. UPLAN has the same limitation. LEAM, SLEUTH, TRANUS and UrbanSim effectively address transportation within the model; however, their implementation is more suitable at a regional scale. Also, UrbanSim has an excellent policy framework, and is a free download from the developer's website; however, there is a learning curve associated with using the software. Understanding and operating the model would take time. Additionally, investing in this model would require additional staffing support.

Additionally, unlike UrbanSim, SLEUTH has no policy analysis capabilities, limiting its usefulness for the Eastern Region.

A GIS based decision support tool such as: Community Viz , What If?, NatureServe Vista, Smart Places and INDEX, are available at moderate costs, have a low learning curve, and can be integrated with GIS software. Smart Places and What If? are scenario based models that visually represent the scenario; however, Community Viz and INDEX are better suited to address the growth related concerns identified. These models can perform a build out analysis and can model water and sewer infrastructure, water quality and transportation. They also have a wide range of applications across the United States at the city and county levels. NatureServe Vista's strength is in modeling conservation and environmental concerns and not in transportation or residential growth. Although the model is marketed as being a useful tool for sensitive lands around military bases, it lacks the broad focus needed, as communicated by those who were interviewed.

CHAPTER SIX: RECOMMENDATIONS AND CONCLUSION

The interviews revealed a need for a model or models at the city and county level that is cost effective, integrates with GIS, performs a build out analysis, addresses transportation, residential development and water quality, and has a short learning curve. Future needs might also stimulate an interest in a model that can evaluate conservation and environmental concerns; however, this was not discussed in the interviews that were held. Based on these results and the analysis of models, the following recommendations are made. The recommendations are broken into two types: those that are focused on city and county level tools of use and those appropriate for regional modeling in the Eastern Region.

City and County Level Recommendation

Recommendation One

It is recommended that a GIS-based planning support system be installed at the city and county level. Appropriate models are as follows: Smart Places, What If?, INDEX, Community Viz and NatureServe Vista. Of these five models, Community Viz would be the most suited and well rounded to address the identified concerns. This model can address all the issues mentioned by planners and stakeholders in the interview process but it can also address habitat fragmentation and can be used by people with varying skill levels ranging from novice to advanced GIS users. It is also a cost effective platform with a purchase price of $750.00 (Placeways 2009). Although Community Viz can not address land cover change and transportation interactions as well as TRANUS, UrbanSim or LEAM can do, it can be easily integrated and learned by staff, which would help in making better informed decisions to guide future growth.

Regional Level Recommendations

Recommendation Two

Another option to consider is employing a more expensive and sophisticated modeling system such as TRANUS, UrbanSim or LEAM at the regional level. Since time, money and staffing were potential problems for the individual counties, having a regional organization to monitor growth concerns would be useful. If a regional model was used then hiring an outside organization to run the model and perform regional analysis would be advised. Doing so would consolidate all data and land use information under one organization allowing for better analysis. Results obtained could then be communicated to the public, the planning community and the Military Growth Task Force through meetings and monthly visioning exercises. The key to using a regional model would be to make sure there is a consistent line of communication with Military Growth Task Force counties, as well as politicians, policy makers and military liaisons. Without this communication, the model would prove useless in planning for future growth.

Recommendation Three

The third possibility is to create a new model to address the growth related concerns specific to Onslow and Craven Counties, and have an outside organization in charge of creating, running and calibrating the model. Having a central organization that collects and analyzes information generated by a land use change model would create cohesiveness and help bring stakeholders together to plan for growth and development. Additionally, hiring an outside organization would allow for more sophisticated modeling platforms to be created, compared to what could be utilized at the county level. The key to the success of this endeavor would be an open line of communication between those running the model, the military growth task force, the regional and county level planning agencies, the military base and environmental organizations.

CONCLUSION

This paper has presented an analysis of 15 widely used land-use change models and assessed their applicability to the Eastern North Carolina Region. With continued growth and currently limited coordination among municipalities, it is important to consider tools that can help in monitoring and forecasting trends for the future. As the analysis, showed there are a wide range of models with varying capacities, sophistication and cost and choosing the right model is crucial for meeting defined goals. It was clear from the interviews that there are common concerns across municipalities and these concerns can be addressed through a land-use change model.

In conclusion, planning for growth in Eastern North Carolina is important due to the influx of new military personnel coming to the region, as well as the potential for residential growth and development in the future. A land use change model provides a useful tool that, if used appropriately, would help to make better informed decisions and to justify those decisions to the public and amongst planning offices. Additionally, incorporating the same model across towns, city and counties within the Eastern region would encourage more collaboration and communication among municipalities, and insure adequate technical resources as growth is planned for in the future. One of the challenges with implementing a model; however, is that GIS departments are not always housed in the planning department and are not necessarily planning-focused. Also, the data availability of each county, dictates the level of analysis that can be completed with a model. However, with the release of the Strategic Lands Inventory data DVD as well as the web-based GIS interface that is under construction by the NC Center for Geographic Information and Analysis, more consistent data is becoming available for use in this region, and will be able to be used within a chosen modeling application. If the Eastern Region implements the recommendations in this paper, then it would make progress in ensuring well-planned and future coordinated growth.

APPENDICIES

APPENDIX A: INTERVIEW PROTOCOL

Questions for key stakeholders at the local level (town, city, county)

I. Issues

1. What are the main growth-related issues or challenges facing the (*town, city, county*) today?

    Prompt: traffic congestion, overcrowded schools, loss of open space, water quality?

2. What growth-related issues is the (town, city, county) likely to face over the next 10-20 years?

    Prompt: What will be the (*town's, city's, county's*) biggest challenges?

II. Trends

3. How has the (*town, city, county*) changed over the last 5-10 years?

    Which areas have grown the fastest/slowest?
    Has there been much growth near the military bases?

4. How do you think the (*town, city, county*) will change in the next 10-20 years?

    Prompts:
    What land use changes do you anticipate?
    Where is most of the growth likely to occur?
    What is driving that growth?

III. Needs/Goals

5. What infrastructure will be needed to serve future growth?

    Prompt: water and sewer, roads, open space

6. How would you like to see the area develop over the next 10-20 years?
7. Where should new growth be located?

    Prompt: In areas with existing infrastructure?

8. Are there some areas that are unsuitable for growth?

    Prompt: Should the (town, city, county) limit growth near military installations or environmentally sensitive areas?

9. What are the (*town's, city's, county's*) conservation goals?

    Prompt: Has the (*town, city, county*) adopted policies or plans to protect working lands, (e.g., forests, farms), open space or wildlife habitat?

IV. Impacts

10. What are the main environmental challenges associated with growth and development?

    Prompt: Water supply, water quality, storm water runoff, flooding, loss of open space…

11. What tools can be used to balance growth, quality of life and environmental protection in the region?

Prompt: conservation easements, acquisition of sensitive lands, green development (e.g. LEED), coordinated planning, …

V. Planning/Modeling Capabilities

12. How large is your planning department?
    How many people work in the department?
13. Has the (*town, city, county*) prepared a land use plan or comprehensive plan?
    When was the plan last updated?
    (Note: Coastal counties will have a CAMA land use plan)
14. If yes, how useful is the plan in guiding growth?
    Prompt: Do elected officials typically refer to the plan when making decisions about development?
15. What are your GIS capabilities?
    Prompts: Do you have a GIS person (technician) on staff?
    What GIS software do you use?
16. Do you have access to any of the following data (in digital format?):

	Yes	**No**
Parcel level data		
Land cover data		
Land value (current and historic)		
Location of building footprints		
Location of infrastructure (water, sewer, rail, etc)		
Parks and other public lands		
Zoning		
Street network		
Employment by zone (which subarea?)		
Stream network		
Wetlands		
Other sensitive areas (e.g., groundwater recharge)		
Topography (DEM/Lidar)		
Demographic data (other than Census)		

17. Is there any data you need but don't have, or don't have access to?
    Prompt: What data do you not have access to?
    What data would you like updated more frequently?

18. What are your computer modeling capabilities: Does the (*town, city, county*) have the capability—the technology and financial resources—to develop computer models that predict future changes in land use?

19. What tools are needed to support local as well as regional land use planning efforts?

> Prompt: Computer models of land use change, GIS, build out analysis, …

VI. Coordination/Collaboration

20. How closely do you work with other jurisdictions (towns, cities, counties) in planning for future growth?

> Prompt: In addition to the Military Growth Task Force, do you work directly with other jurisdictions on particular issues? What issues?

21. In addition to the issues being addressed by the 10 working groups on the MGTF, are there other (regional) issues you share in common with other jurisdictions that are not being addressed?

APPENDIX B: INTERVIEW CONTACTS

Interview Contact	Position	Location	Department	Interview Date
Annette Stone	Senior Planner	City of New Bern	Planning Department	3/25/2009
Harold Blizzard	County Manager	Craven County	Adminstration	3/25/2009
Reginal Goodson	Planning Director	City of Jacksonville	Jacksonville MPO	3/26/2009
Jennifer Holland	Planner I	Town of Swansboro	Planning Department	3/26/2009
Walter B. Hartman	County Manager	City of New Bern	Adminstration	3/26/2009
James Bender	Deputy Director	Jacksonville	Military Growth Task Force	3/26/2009
Scott Shufford	Planning Director	Onslow County	Planning Department	3/27/2009
Angela Cole	County Manager	Onslow County	Planning Department	3/27/2009
Angie Manning	Planner	Onslow County	Planning Department	3/27/2009
Matthew Stuart	Planner	Onslow County	Planning Department	3/27/2009

APPENDIX C: OVERVIEW OF MODELS REVIEWED

TABLE 2: LAND USE CHANGE MODELS BAED ON OUTPUT, EXPERIENCE, AND COST

Model Name	Model Type	Developer	Output	Experience Needed	Cost
CUF-2 (second generation California Urban Futures)	agent based/discrete choice	John Landis, Institute of Urban and Regional Plannin,g University of California at Berkeley	new development and redevelopment acreage total by land use type in tabular format; maps of existing and projected development (by land use type)	requires land use planning and statistics experience	not available for direct purchase: contact developer
UrbanSim	agent based/discrete choice	Paul Waddell, Daniel J. Evans School of Public Affairs, University of Washington	outputs are by zone and are available at parcel or grid cell level in ASCII format and by using ArcView	land use planning	free download
SLEUTH (Slope, Land use, Exclusion, Urban, Transportation, Hillshading)	cellular automata	Keith C. Clarke, Department of Geography, Unviersity of California at Santa Barbara	aset of GIF image files that can be merged into an animation or brought into a GIS as data layers.	land use planning	free download
LEAM	cellular automata	University of Illinois with funding from the National Science Foundation	series of future land use maps	land use, modeling and statistics experience	$10,000 +
INDEX	GIS Based Planning Support System	Criterion Planners/Engineers, Inc.	GIS maps	land use planning	$10,000 +
NatureServe Vista 2.0	GIS Based Planning Support System	NatureServe	map and graphical outputs	project coordination and management, geographic information services, data management, environmental experience	contact developer
Smart Places	GIS Based Planning Support System	Electric Power Research Institute (EPRI). Contact: Paul Radcliffe	GIS maps	none	contact developer
What If?	GIS Based Planning Support System	Dr. Richard E. Klosterman (as Community Analysis and Planning Systems, Inc.)	GIS maps and reports	land use planning	$1-$5000
TRANUS	spatial input-output	Modelistica	graphical, tabular and GIS map outputs	land use planning	$5,001-$10,000
UPLAN	spatial input-output	Robert Johnston, Department of Envrionmental Science and Policy, University of California at Davis	grid maps: ArcView layouts; Analysis report, Assumptions Report, Image Files	land use planning	free download
METROSIM	spatial input-output	Alex Anas & Associates	basic distribution information by zone in a desired format	none	$10,000 +
MEPLAN	spatial input-output	Marcial Echenique & Partners Limited	employment by sector, population by income group, households by car ownership group, land area by activity, floor space by activity, price by floorspace/land type	land use planning	$10,000+
IRPUD	spatial input-output	Michael Wegener, Institute of Spatial Planning, University of Dortmund, Germany	graphical and tabular outputs	land use modeling	contact developer
LUCAS	spatial input-output	Michael W. Berry, Department of Computer Sciences, University of Tennessee	statistical and graphical outputs	land use modeling	free download

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